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Screening for formulas of complex substrates for seedling cultivation of tomato and marrow squash

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Abstract

Organic complex substrates mixed by vinasse, mushroom residue and cattle manure as the main materials were conducted to screen proper substrates for the growth and development of tomato and marrow squash seedlings. The results indicated that it's practical to use mature vinasse, mature mushroom residue and mature cattle manure as nursery substrates. After screening for formulas of complex substrates for seedling cultivation of tomato and marrow squash, T7 and T14 had the best effect for the processing tomato and marrow squash seedling, the total primary nutrient of which were 3.07%, 2.97% respectively, more than that of CK.

Keywords: Seedling nursing; Substrate formula; Tomato; Marrow squash

1. Introduction

Factory growing seedling is an effective measure for vegetables industrialization and the basis of vegetables to obtain high and stable yield [1-2]. Nursery substrate plays an important role in factory seedling cultivation system. Now turf resource as raw material for matrix is mainly adopted in many countries, however, it's unevenly distributed and nonrenewable. So the price of turf gradually rises in recent years, which increases the cost of seedling cultivation. Therefore, exploration of localized formula for matrix with easily taken material and low price has received widespread attention at home and abroad [3-5]. Studies showed that, solid wastes from agricultural farming and breeding industry could be used as high value-added matrix and formulated as composite substrates which achieved certain physicochemical

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property standards to replace turf and to be used for vegetables' tray seedling cultivation. Many studies also showed that some materials, such as cottonseed hull, saw dust, carbonized rice hull, sugar residue, sludge and waste material, etc., could be used for matrix of seedling cultivation[6-9]. Moreover, turf resources could be replaced and reduced by such materials. However formulas for matrix of seedling have not been studied and still lacked in Wuhan region. According to actual needs for seedling production, composes different formulas of matrixes with organic solid wastes as materials, studies their effects of seedling cultivation on tomato and marrow squash to expect to screen one or several localized formulas, which can better cultivate strong seedlings and reduces the cost for seedling, provides new ways to use matrixes for organic wastes including vinasse and mushroom residues, and some references for industrial seedling cultivation as well.

2. Materials and methods

2.1. Materials for test

Cattle manure was purchased from Wuhan Kyushu Dairy Co., Ltd. Mushroom residues, vinasse, bran and lime were purchased from Wuhu Farm of Huangpi, Wuhan. 99 dynamic fermentation agent, pearl stone and 72-hole trays (L×W×H:540mm×280mm×45mm) were purchased from Wuhan Weierfu Seedling Co., Ltd.

2.2. Varieties for test

Marrow squash named Large White seed were purchased from Wuhan Weierfu Seedling Co., Ltd. Tomato named American Powder King were purchased from Wuhan Duoluokou Agricultural Market.

2.3. Initial screening for formula of mixed matrixes on tomato

The mixture ratio by volume showed in Table 1, the mixed materials had thoroughly decomposed for matrix formulas. Tests were carried out in greenhouse at Wuhu Base of Wuhan Academy of Agricultural Sciences and Technology, sowed tomato seeds after germination in 72-hole tray, each treatment for 3 replications. The substrates with 2:1 volume ratio between turf and pearl stone were used as a control (CK). Took 11 seedling samples during two true leaves stage、four true leaves stage for measuring.

Table 1. Mixture ratio for different formulas of undecomposed matrixes (by volume)

formulas	vinasse	mushroom residue	cattle manure	formulas	vinasse	mushroom residue	cattle manure
T1		3	2	T10	2	2	1
T2		3	1	T11	1	1	1
T3		9	1	T12	2	1	1
T4	3		2	T13	1	2	1
T5	3		1	T14	4.5	4.5	1
T6	9		1	T15	1		
T7	2	1		T16		1	
T8	1	1		T17			1
T9	1	2		CK	V_{turf}: $V_{pearl\ stone}$=2:1		

2.4. Re-screening for formula of mixed matrixes for marrow squash

Further screened formulas of matrixes from better effects of seedling cultivation for tomato obtained in step 2.3, followed step 2.3 to treat marrow squash seeds and took 11 seedling samples for testing indicator separately at stages of one true leaf, two true leaves and three true leaves for seedlings of marrow squash.

2.5 Testing indicators and methods for quality of seedling cultivation

Recorded rate of germination on day 10 after sowing and tested seedling Spad value by the SPAD-502 chlorophyll meter on day 35. Took samples of eleven plants at different growing times, measured plant height (for plant height, use ruler with calibration of millimeter to measure length between position of rootstalk and growth point), stem diameter (used vernier caliper to measure 2/3 roughness of lower part of cotyledon), fresh weight for part on the ground and part under the ground and dry weight for part on the ground and part under the ground [10]and calculated root-shoot ratio (dry weight for part under the ground /weight for part on the ground) and health index [(stem diameter/plant height) × dry weight of entire plant]. Adopted SAS software (8.0) for data analysis.

2.6 Measuring method for physicochemical property of formula of matrix

Matrix EC and pH Measurement: Used 1:5 leaching liquor method to extract solution to be measured, used Italian Hanna Company's Hi98304 conductivity meter to measure EC value and used Mettler Lab's pH meter（FE20/EL20）to measure pH value. Before disc loading, random took samples and mixed them even, refered to organic fertilizer's industrial standard (NY525-2011) by Ministry of Agriculture of the People's Republic of China and Soil Agrochemical Analysis Handbook [11], adopted potassium dichromate colorimetry for testing organic matter, semi-micro Kjeldahl method for total nitrogen, vanadium molybdenum yellow colorimetry for total phosphorus and flame photometry method for total potassium.

3. Results and analysis

3.1. Germination situations of different formulas to tomato seedlings

At tenth day after sowing, all treated germination rates had exceeded 80% and germination was neater. Highest germination rate was T7 formula, which was 98.59%, and next ones were T14 and T4 formulas for 97.65%. The germination rates of above three treatments were higher than control, and the lowest one was T6 for 87.79%.Through analysis of variance, except for treatment of T1, T2, T6, T15 and T16, other 12 kinds of mixed matrixes had no significant difference with control ($p<0.01$).

3.2 Spad value for tomato seedling

It is generally believed that SPAD value is a parameter to measure relative content of plant chlorophyll and size of its value is positively correlated to content of chlorophyll inside leaf. SPAD value for 17 kinds of different formulas treated tomato seedlings leaf had been measured, the results showed that SPAD value of T12 formula was biggest for 30.3, next ones were CK and T16 which were separately 29.9 and 29.8, and value for T3 was smallest which was 25.5. Through analysis of variance, except for treatment of T3 other mixed matrixes had no significant difference with control ($p<0.01$).

3.2. Effects on morphological index for tomato seedlings during different periods

At stage of two true leaves and one heart, the value of various indicators from 17 kinds of nursery substrates were higher than control, but the difference between them were not significant, such as stem diameter, total fresh weight, total dry weight and health index. The value of control's plant heights, stem diameters and total dry weights were higher than other treatments. Comparison for most of formulas for matrixes to plant height of tomato seedling was very significant ($p<0.01$). The value of control's plant height was the biggest, next ones were T2 and T1 and the smallest one was formula T12. Health index of formula T8 was highest, next ones were T9 and T1, but the difference for comparison was not significant.

Table 2. Total 17 kinds of decomposed matrixes' various indexes for tomato seedling cultivation (two true leaves)

treatments	stem diameter(cm)	plant height(cm)	total fresh weight (g)	total dry weight (g)	root-shoot ratio	health index
T1	0.157a	7.23AB	1.3387a	0.0753a	0.106b	0.00164ab
T2	0.146ab	7.32AB	1.1790ab	0.0679abc	0.122ab	0.00136abc
T3	0.142ab	6.53ABCDE	0.8901c	0.0539c	0.123ab	0.00115bc
T4	0.134b	6.04CDEFGH	0.8783c	0.0485c	0.120ab	0.00108c
T5	0.146ab	6.34BCDEF	1.0884abc	0.0678abc	0.131ab	0.00157abc
T6	0.137b	5.88DEFGH	0.8607c	0.0500c	0.130ab	0.00117bc
T7	0.149ab	6.94ABC	1.1254abc	0.0689abc	0.114ab	0.00154abc
T8	0.146ab	5.88DEFGH	1.0718abc	0.0684abc	0.143ab	0.00171a
T9	0.145ab	6.53ABCDEF	1.2123ab	0.0746ab	0.128ab	0.00166ab
T10	0.144ab	5.71EFGH	0.8577c	0.0515c	0.127ab	0.00130abc
T11	0.134b	5.48GH	0.8600c	0.0525c	0.152ab	0.00129abc
T12	0.147ab	5.26H	0.8603c	0.0546bc	0.149ab	0.00152abc
T13	0.133b	6.50ABCDEF	0.9968bc	0.0635abc	0.126ab	0.00130abc
T14	0.139ab	6.72ABCDE	1.0070bc	0.0619abc	0.121ab	0.00129abc
T15	0.150ab	6.92ABC	1.0671abc	0.0573abc	0.133ab	0.00124abc
T16	0.149ab	6.76ABCD	1.1226abc	0.0689abc	0.156a	0.00152abc
T17	0.141ab	5.54FGH	0.9494bc	0.0580abc	0.137ab	0.00148abc
CK	0.156a	7.41A	1.1378abc	0.0758a	0.125ab	0.00159abc

Note: Different capitalized letters marked behind the same row of data show 1% significance of differences and lowercase letters show 5% significance of differences.

Table 3. Total 17 kinds of decomposed matrixes' various indexes for tomato seedling cultivation (four true leaves)

treatments	stem diameter(cm)	plant height(cm)	total fresh weight (g)	total dry weight (g)	root-shoot ratio	health index
T1	0.246a	13.39abc	5.5979ab	0.3993ab	0.090b	0.00755ab
T2	0.237abc	12.24abcd	4.6325bc	0.3997ab	0.086b	0.00777ab
T3	0.225abc	11.95abcd	4.9561abc	0.2750bc	0.087b	0.00519b
T4	0.241ab	14.09a	5.3986abc	0.3630abc	0.086b	0.00626b
T5	0.251a	12.53abc	5.5523ab	0.3533abc	0.092b	0.00717ab
T6	0.214bc	13.29abc	5.3302abc	0.3351abc	0.088b	0.00622b
T7	0.233abc	14.08a	5.7129ab	0.3965ab	0.094b	0.01046a
T8	0.227abc	12.23abcd	5.2408abc	0.3671abc	0.087b	0.00678ab
T9	0.234abc	13.82abc	5.6954ab	0.3942ab	0.077b	0.00671ab
T10	0.252a	13.64abc	6.096ab	0.2540c	0.354a	0.00485b
T11	0.245a	11.82bcd	4.9216bc	0.3048abc	0.084b	0.00635ab
T12	0.241ab	11.73cd	5.2510abc	0.3473abc	0.091b	0.00719ab
T13	0.236abc	11.77cd	4.8872bc	0.3516abc	0.086b	0.00711ab
T14	0.231abc	12.59abc	5.3420abc	0.3792abc	0.094b	0.00704ab
T15	0.225abc	13.97ab	4.9456abc	0.3230abc	0.076b	0.00522b
T16	0.210c	10.29d	3.8999c	0.2976bc	0.131b	0.00602b
T17	0.253a	13.57abc	6.5062a	0.4322a	0.084b	0.00803ab
CK	0.234abc	12.63abc	5.0858abc	0.3454abc	0.076b	0.00644ab

Note: Different lowercase letters show 5% significance of differences.

During the period of four true leaves and one heart, the differences of stem height between all treatments and CK were not significant. However, stem diameters of T1, T10, T11 and T17, etc were more wider than CK. The difference of plant heights between most treatments and CK were not significant, but the values of plant heights of T7 and T4 were higher than CK. The difference of root-shoot ratios between treatments and CK were not significant, except for T10 ($p<0.05$). The difference of fresh weights, dry weights and health index between different formulas and control were not significant, but the health index values including T7, T1, T2 and T17 etc. were much higher than CK, especially for formula T7.

Generally seedling cultivation was neither better nor worse for its health index. A series of morphological indexes tested for tomato seedlings, the result showed that comparison for health index in all formulas were not significant. Based on datas of the above research and observation for character index, the results indicated that the quality of tomato seedling growth was related to formulas for matrix. According to the performance of seedling growth on 17 various matrixes at different stages, initially nine formulas were selected to cultivate the seedling of marrow squash, including T4, T5, T7, T8, T10, T11, T12, T13 and T14.

3.3. Rate of germination for marrow squash

The results on the rate of germination showed that marrow squash seedling of T8 came out fast and evenly. On eighth day after sowing the rate of T8 seedling germination had reached 60%, far higher than that of CK (13.3%), the difference between them were significant at 5% level. On ninth day, the rates of all treatments germination had a rapid increase. On tenth day the rates of all treatments germination exceeded 80%, the highest of which was T8, followed by T7 and T14. The analysis of variance showed that the difference between T8, T7 and CK reached at the 5% significant level.

3.4. Different formulas for matrixes' effects on morphological index for marrow squash seedlings

Seen in Fig.1, stem diameter of control was nothing like as good as these compound matrixes. In the period of two true leaves and one heart, the value of T11 stem diameter was the highest for 0.4908cm, and the lowest one was CK, only 0.3605cm. The differences between 9 kinds of formulas and CK were very significant at 1% level. During three true leaves stage, T14 stem diameter was increased obviously, the average value of which was 0.5037cm, followed by T14, and CK was still the lowest one for 0.3747cm. The analysis of variance showed that the difference for stem diameter between 9 kinds of formulas and CK had reached at the 1% significant level. It showed that mixed matrixes could culture stronger seedlings. Seen in Figure 4, 9 kinds of matrix formulas didn't affect largely on plant height of marrow squash seedling at different stages. By analysis of variance, the difference of plant height between 9 kinds of formulas and control was not significant ($p<0.05$).

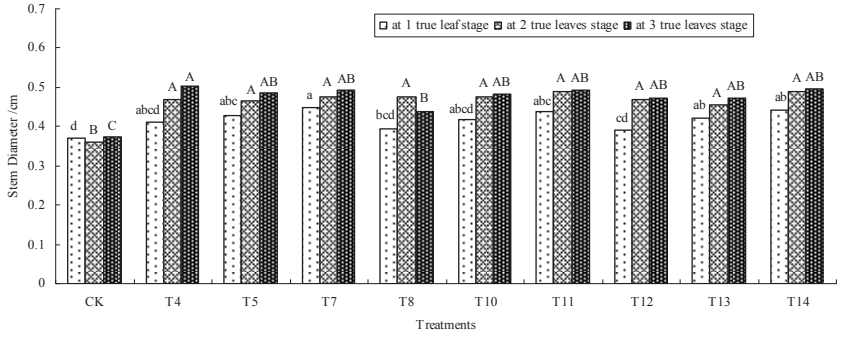

Fig. 1. Comparison of different formulas on stem diameter of marrow squash seedling

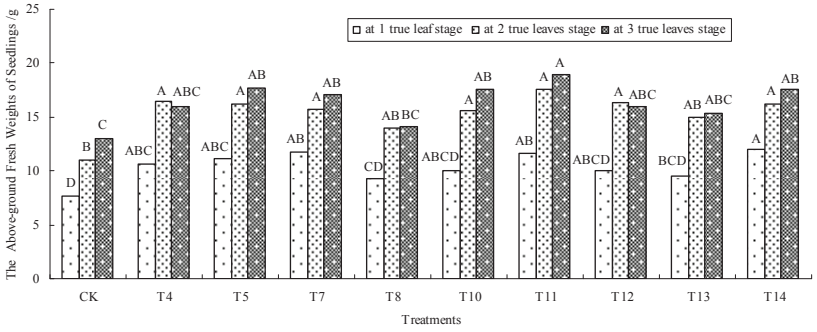

Fig. 2. Comparison of different formulas on the above-ground fresh weights of marrow squash

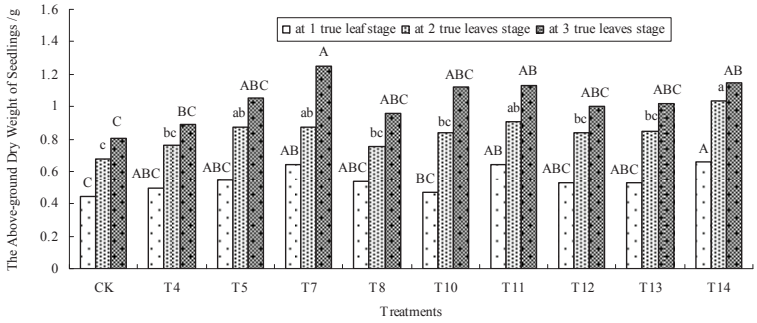

Fig. 3. Comparison of different formulas on the above-ground dry weights of marrow squash

Known from fig.2 and fig.3, the differences of above-ground fresh weight and dry weight of marrow squash seedlings among various treatments were obvious during different periods. At stage of one true leaf and one heart, the above-ground biomass accumulated on T14 was the biggest, which was 12.036g, followed by T7 and T11, and control was the smallest. At stage of two true leaves, except for formula T8 and formula T13, the difference of the above-ground fresh weight between other 7 kinds of formulas and CK were very significant at 1% level. At stage of three true leaves, the above-ground fresh weight of T11 was the heaviest for 18.9g, followed by T5 and T14, much more than control which 13.038g. Besides T4, T8, T12 and T13, the difference between other 5 treatments' above-ground fresh weights and compared were very significant ($p<0.01$).

The data of the above-ground dry weight accumulation were showed in Fig.3. At stages of one true leaf and two true leaves, the above-ground dry weight of T14 was the heaviest, respectively 0.6599g and 1.0333g. At stage of three true leaves, the dry weight of T7 was the heaviest, which reached 1.2498g. No matter what stage, the above-ground dry weight of control was always the lowest. The analysis of variance showed that at the stage of one true leaf the difference between T14 and control reached at the 1% significant level, at stage of two true leaves difference between T5, T7, T11, T14 and CK reached at the 5% significant level, and T7, T11, T14 and CK reached at the 1% significant level during 3 true leaves. The results indicated that, compared with CK, 9 kinds of formulas could promoted marrow squash growth and increased the above-ground dry weight, especially T7, T11 and T14 performanced excellently.

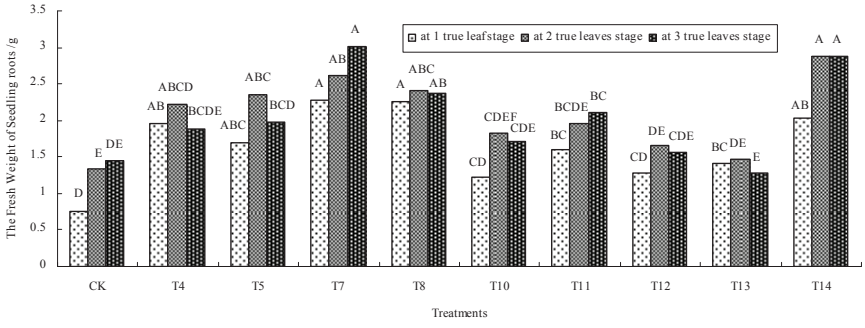

Fig. 4. Comparison of different formulas on the fresh weights of seedling roots for marrow squash seedlings

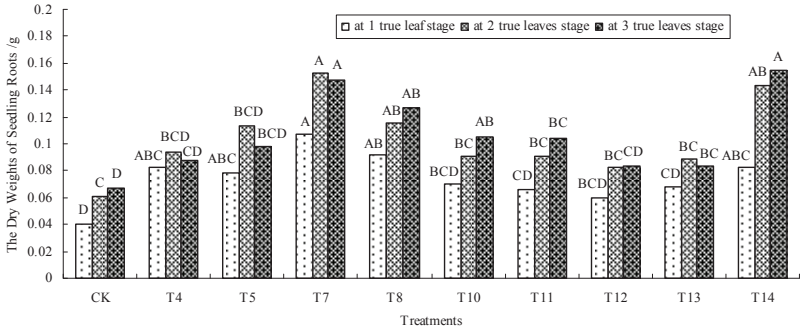

Fig. 5. Comparison of different formulas on the dry weights of seedling roots for marrow squash seedlings

The data of fresh weights of seedling roots were showed in Fig.4. Overall, the performance of T7 and T14 fresh weights of seedling roots were the best at three different stages, then was T8. At stage of one true leaf, the value of T7 fresh weight of seedling roots was the biggest and the next one was T8, respectively 2.2703g and 2.2628g, and the smallest one was control, which only 0.7611g. The analysis of variance showed that at the stage of one true leaf the difference between other 7 kinds of formulas and control reached at the 1% significant level, except for formula T10 and formula T12. At stage of two true leaves and three true leaves, the difference between T4, T5, T7, T8, T14 formulas and control were significant at the 1% significant level. In addition, the fresh weights of seedling roots from T14 and T7 formula were much better than other treatments.

The data of dry weights of seedling roots was showed in Fig.5. The results of dry weight of seedling roots were similar to the fresh weight of seedling roots. The value of the dry weight of seedling roots from T14 and T7 were also much bigger than other treatments, followed by T8, and the value of CK dry weight was always the lowest at different stages. For example, at stage of one true leaf and one heart, the value of T7 dry weight of the seedlings roots was 0.1069g, the next one was T8, and the smallest one was control, which only 0.0405g. The analysis of variance showed that the difference between T7, T8, T14 and control reached at the 1% significant level during different stages. It was worth mentioning that some marrow squash seedlings were infracted by underground pests to cause roots of marrow squash to be born, therefore, some data of fresh weight and dry weight at stage of three true leaves was lower than those at stage of two true leaves. Over all the biomass accumulation of various formulas was higher than that of CK.

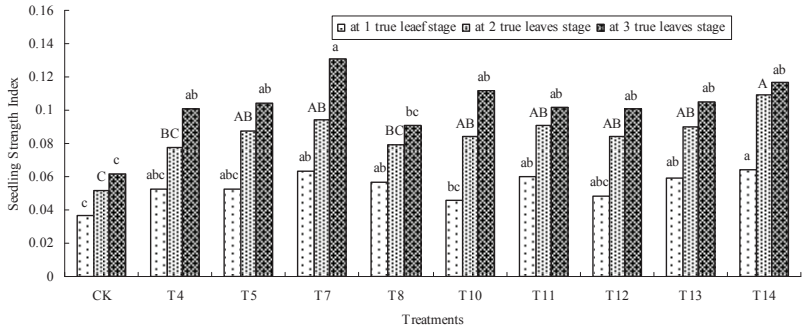

Fig. 6. Different formulas for matrixes' effect on health index of marrow squash seedlings

Root-shoot ratio is an important index to evaluate the quality of strong seedling. Normally when the value of root-shoot ratio is getting bigger, the seedling grows stronger. Root-shoot ratios of marrow squash seedling reduced gradually along the seedling age raised, it might be related to root of marrow squash seedling's born by underground pests. Under the same condition of cultivation and management, the performance of root-shoot ratio of T7 and T8 were better than other treatments.

Seen in Fig.6, health index of marrow squash seedling increased as seedling age raised. Compared with all formulas, the health indexes of T7 and T14 were much better. At the stage of one true leaf and one heart, the value of T14 health index was the highest, followed by T7 and T11, which respectively 0.06453, 0.06342 and 0.060062, and the lowest one was CK. The differences between T7, T8, T11, T13, T14 and CK were significant at 5% level. At the stage of two true leaves, the first three order of health index value was: T14＞T7＞T11, the value of which respectively 0.10907, 0.09376 and 0.09062, the smallest one was CK, the value of which 0.05154. Except for T4 and T8, the difference between other treatments and CK was very significant at 1% level. Similarly, at stage of three true leaves and one heart, the highest value of seedling health index was T7 for 0.13074, followed by T14 and T10 which were respectively 0.11685 and 0.11145, and CK was the lowest, only 0.06126. Except for T8, the differences between other 8 kinds of formulas and control were significant ($p<0.05$). It was clear that most of mixed substrates were helpful for strong seedling of marrow squash, especially T7 and T14.

3.5. Chemical properties of selected nursery substrates

Through comparison on the effects of seedling cultivation for tested tomato and marrow squash, formula T7 and T14 was regarded as potential matrix for seedling cultivation of melons and vegetables, so it was necessary to test their physicochemical property. Seen from Table 4, the physicochemical property of T7 and T14 was similar, but they were quite different from CK. pH value of matrix is an important parameter, and appropriate range was generally from 5.8 to 7.0 under acidic condition [12]. T7 and T14 presented weakly alkaline, and total nitrogen contents were similar to CK. However, content of total phosphorus and potassium were over two times than those of CK. Content of total nutrient for T7 and T14 was higher. In addition, Ec value is an index to reflect the content of matrix's soluble salt. Studies showed that, secure Ec value for crop's growth should be ＜2.6 mS/cm, most appropriate value was 2.0 mS/cm[13]. Seen from Figure 5, Ec value of T7 and T14 was four times higher than CK, but within appropriate range.

Table 4. Measurement for physicochemical property of T7 and T14 formula

treatments	organic matter (%)	pH	total nitrogen(%)	total phosphorus(%)	total potassium (%)	Ec value (mS/cm)
T7	48.34	7.38	1.44	1.07	0.56	0.74
T14	47.67	7.29	1.28	1.15	0.54	0.77
CK	40.23	6.10	1.35	0.40	0.21	0.18

4. Discussion

The results proved that the quality of seedlings growth for tomato and marrow squash was related to the composition of the nursery substrate. During tests for tomato seedling cultivation, the effect of seedling cultivated by compound substrates containing ingredient of vinasse was the best, secondly

seedling cultivated by mixed matrixes including mushroom residue and cattle manure, and last cultivated by single matrix including vinasse or mushroom residue or cattle manure. During tests of seedling cultivation for marrow squash, there were significant difference effects of seedling cultivation among various treatments. The effects of seedling cultivation on formula T7, T14, T8 and T11 were better, especially T7 and T14, like stem diameter, accumulation of dry weight and health index, existing significant difference compared with CK. These results indicated that decomposed vinasse, mushroom residue and cattle manure could be used as matrixes for seedling cultivation to replace turf resource.

Organic solid wastes are widely spread, renewable, low cost, and can be used as localized seedling cultivation matrixes after they are fermented and decomposed. Although traditional turf is taken as seedling cultivation matrix, growth vigor of seedling is better, due to its continual exploitation, turf resource is getting fewer and fewer. Especially it is allocated and transported from Northeast China to China's middle, lower reaches of Yangtze River and South China, which raises the cost of seedling cultivation. Considering economic benefits, social benefits and sustainable development as whole, seedling cultivation matrixes which are applicable to mixture ratio and take organic solid wastes as main raw materials are more applicable to needs for production.

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